MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 3, 2022/2023

EEE1046 – ELECTRONICS III

(All sections / Groups)

4 OCT 2023
9:00 AM – 11:00 XM
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 10 pages (including the Cover Page and the Appendix) with 4 Questions only.

2. Attempt **ALL** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please write all your answers in the Answer Booklet provided.

Question 1

(a) Operational amplifier (op-amp) can be used to design an inverting summing amplifier having two or more input signals, where the resultant output signal is proportional to the algebraic sum of the input signals.

(i) List **TWO** ideal characteristics of an op-amp. [2 marks]

(ii) Consider an ideal inverting summing amplifier circuit, which combines **TWO** input voltages to produce an output voltage. Draw the schematic diagram of the amplifier circuit, clearly indicating the components as follows:

- Series input resistors (R_1, R_2) ;
- Feedback resistor (R_F) ;
- Input voltages (V_{IN1}, V_{IN2}) ; and
- Output voltage (V_{OUT}) . [4 marks]

(iii) Based on the ideal inverting summing amplifier circuit in Part (a)(ii), derive the mathematical expression for the output voltage V_{OUT}. [4 marks]

(iv) Given that the ideal inverting summing amplifier produces an output voltage:

$$V_{OUT} = -(12V_{IN1} + 3.3V_{IN2}) .$$

For a feedback resistor $R_F = 120\ k\Omega$, find the values of the series input resistors (R_1, R_2). [2 marks]

(v) Referring to Part (a)(iv), the waveforms of input signals V_{IN1} and V_{IN2} are shown in Figure Q1(a). Sketch the output waveform V_{OUT}. [4 marks]

(b) An ideal difference amplifier has input voltages that are applied simultaneously to both the inverting (V_1) and non-inverting (V_2) inputs, and produces a resultant output voltage V_{OUT} that is proportional to the voltage difference ($V_2 - V_1$).

(i) Design an ideal difference amplifier circuit which produces an output voltage:

$$V_{OUT} = 18\ (V_2 - V_1).$$

Note: Draw the schematic diagram and indicate the components values on the schematic.

[5 marks]

Continued .....

(ii) Given that the input signals to the ideal difference amplifier are:

$$V_1 = \begin{cases} -0.60\,\text{V}, & \text{for } 0 \le t < 0.05\,\text{s} \\ +0.25\,\text{V}, & \text{for } 0.05 \le t < 0.10\,\text{s} \end{cases} \text{; and } \quad V_2 = 0.1\sin(200\pi t)\,\text{V}.$$

Sketch the output waveform V_{OUT}. [4 marks]

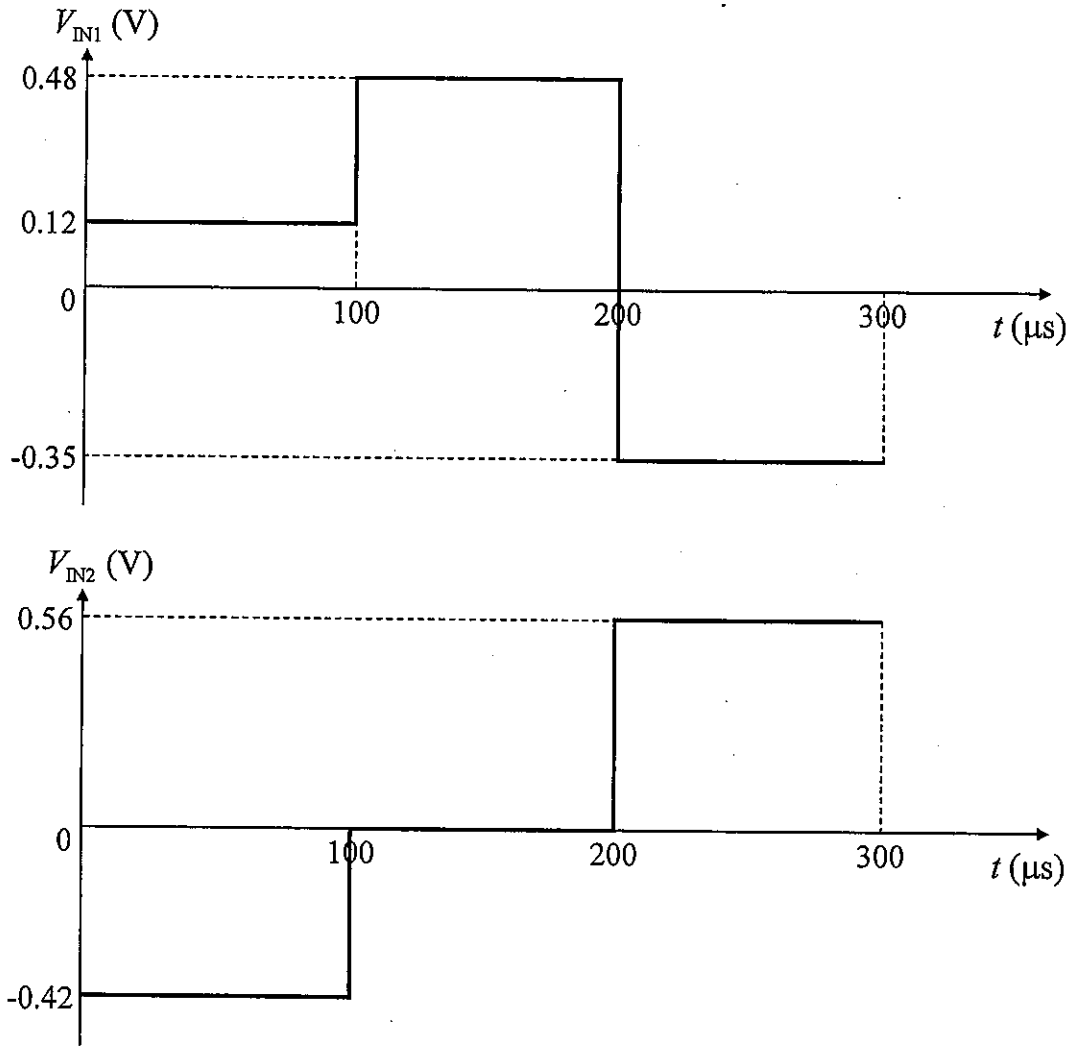

Figure Q1(a)

Continued .....

Question 2

(a) A μA741 operational amplifier (op-amp) is used to construct an inverting amplifier circuit as shown in Figure Q2(a), where the series input resistor R_1 = 12 kΩ and the feedback resistor R_F = 330 kΩ. A resistor R_X is placed at the non-inverting input of the op-amp. The op-amp is non-ideal and has the following specifications:

Table Q2(a)

Parameter	Value
Open-loop voltage gain, A_{OL}	250,000
Open-loop critical frequency, $f_{C(OL)}$	180 Hz
Input offset voltage, V_{IO}	6 mV
Input biasing current, I_B	450 nA
Input offset current, I_{IO}	105 nA

(i) Explain the main function of the resistor R_X. Next, derive the expression for R_X. [2+7 marks]

(ii) Calculate the value of R_X. [2 marks]

(iii) Determine the total output offset voltage V_{OO}. [4 marks]

(iv) Suggest a method to eliminate the output offset voltage. Explain your answer. [3 marks]

(v) Sketch the frequency response of the op-amp (i.e., magnitude of voltage gain $|A_V|$ versus frequency f), clearly indicating the following parameters:

- Open-loop voltage gain, $|A_{OL}|$
- Open-loop critical frequency, $f_{C(OL)}$
- Closed-loop voltage gain, $|A_{CL}|$
- Closed-loop critical frequency, $f_{C(CL)}$ [4 marks]

Continued .....

(b) A non-inverting amplifier circuit has a series input resistor $R_I = 22\ \text{k}\Omega$ and a feedback resistor $R_F = 560\ \text{k}\Omega$. The input signal is given as $v_{in}(t) = 0.34\sin(65{,}000\pi t)$ V. Determine the slew rate of the op-amp. [3 marks]

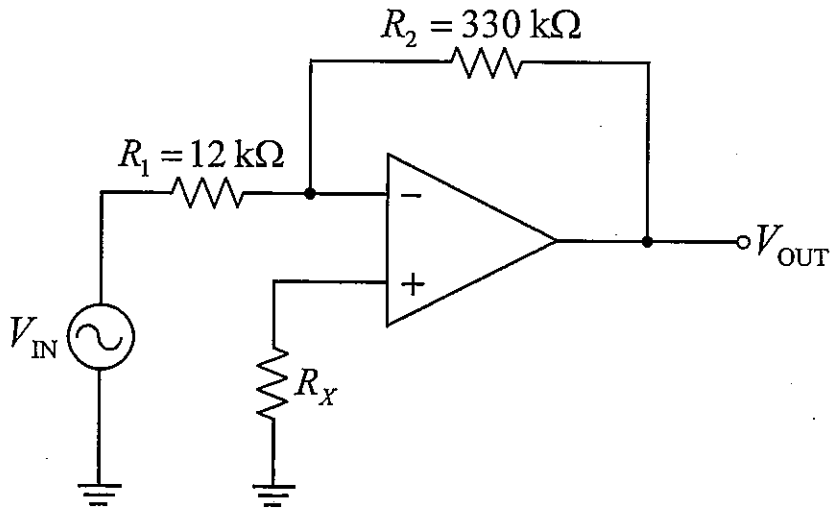

Figure Q2(a)

Continued .....

Question 3

(a) Figure Q3 (a) shows a series feedback voltage regulator using an op-amp as the error detector. The voltage from an unregulated power supply may vary from full-load voltage V_{FL}= 20V to no-load voltage V_{NL} = 25V. A power transistor with a maximum rating of 1 A is to be used as the pass transistor of a 15 V regulator. Given R_1 = 33 kΩ, R_2 = 90 kΩ , h_{FE} of the transistors is 100, the Zener knee current, I_{ZK} is 10 mA. and V_{BE} of the transistor is 0.7 V. At maximum load, by analyzing the circuit;

(i) Design the circuit by computing the value of R. [4 marks]

(ii) If the maximum load, R_L = 1k Ω and assume $I_{C1} = I_{E1}$, determine the maximum power dissipation P_D for the transistor Q_1. Then, compute the efficiency, η of the series feedback voltage regulator. [6 + 5 marks]

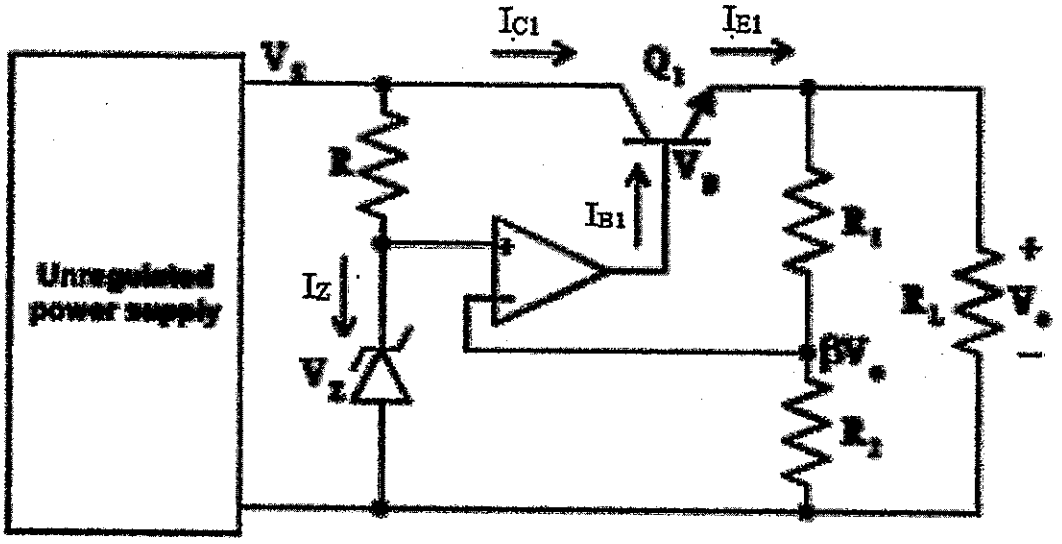

Figure Q3 (a)

Continued .....

(b) A Wien bridge oscillator circuit is shown in Figure Q3(b), where its feedback voltage gain, β is given as:

$$\beta = \frac{XR}{3XR + j\left(R^2 - X^2\right)}$$

Assume the op-amp is ideal. Please take note that X is the reactance of capacitor C.

(i) From the Barkhausen Criterion, derive the formula for oscillation frequency, f_o. [3 marks]

(ii) Determine β and the minimum amplifier gain, A for oscillation. [3 marks]

(iii) For R_1 = 10 and kΩ C = 10 nF, determine the value of R_2 and R for the circuit with oscillation frequency, f_o = 1 kHz. [2 + 2 marks]

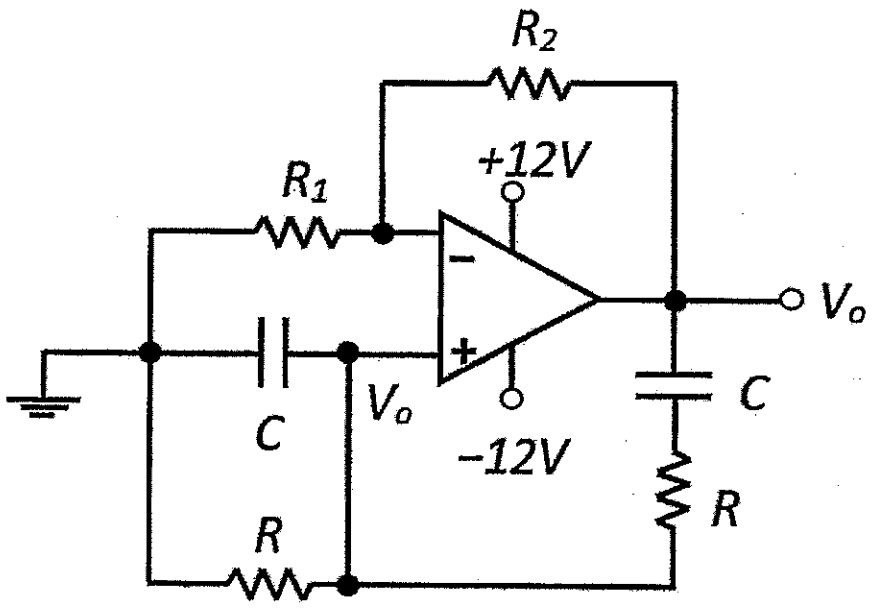

Figure Q3 (b)

Continued .....

Question 4

a) Figure Q4 (a) shows a first-order low pass active filter. By splitting the original circuit into a non-inverting amplifier circuit and filter section and also by using the Laplace's domain *(s)*;

(i) Prove that the overall voltage transfer function equation for the circuit below is:

$$H(s) = \frac{V_O(s)}{V_i(s)} = \frac{K}{1+sRC},$$

where $K = 1 + \frac{R_F}{R_1}$. [6 marks]

(ii) By comparing the equation above with the general form, derive the filter cutoff frequency, ω_o. [2 marks]

(iii) Given that $s = j\omega_o$ and $\omega_o = 2\pi f_o$, design the filter circuit by finding the value of R_1 and R for $f_o = 1$ kHz, $K = 2$, $R_F = 10\ k\Omega$ and $C = 10\ nF$. [4 marks]

(iv) Following the filter information from (iii) and the filter has -20dB/decade attenuation, determine the approximate normalized gain $|A_v|$ in dB at $f = 20$ kHz. [3 marks]

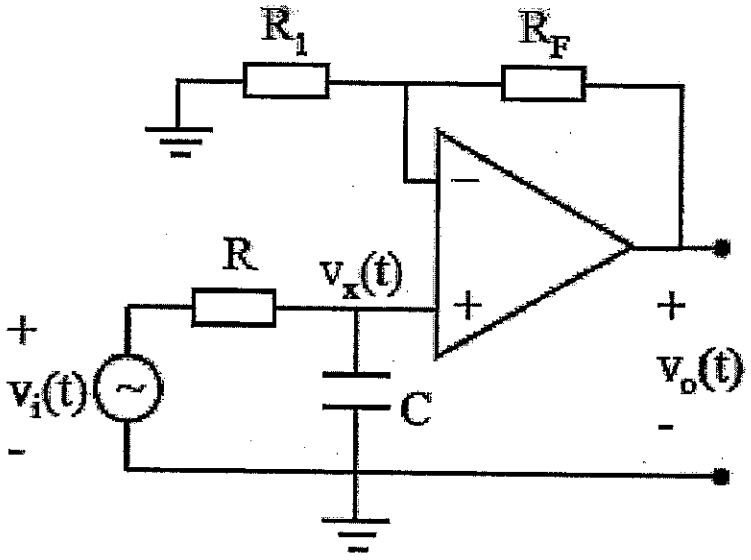

Figure Q4 (a)

Continued .....

(b) Figure Q4(b) illustrates an inverting Schmitt trigger comparator circuit, with maximum output levels of $\pm V_{OUT(max)} = \pm 24$ V. Given that the input signal $v_{in}(t) = 15\sin(2{,}000\pi t)$ V.

(i) Determine the upper trigger point (UTP) and the lower trigger point (LTP) for the comparator circuit. [5 marks]

(ii) Draw the output waveform $v_{out}(t)$ for $0 \le t \le 4\pi$, clearly showing its proper relationship to the input signal $v_{in}(t)$. [5 marks]

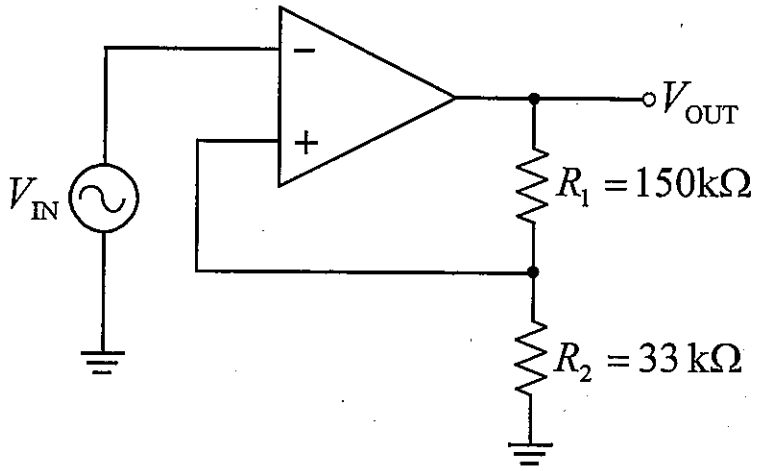

Figure Q4(b)

Continued .....

Appendix: Useful Formulas

$$A_v = A_{ol} = \frac{V_{out}}{V_{in}}$$

$$A_v = A_{cl} = -\frac{R_f}{R_i}$$

Inverting amplifier, $A_{cl} = \frac{V_o}{V_i} = -\frac{R_F}{R_1}$

Non-inverting amplifier, $A_{cl} = \frac{V_o}{V_i} = \left(\frac{R_F}{R_1} + 1\right)$

$$v_d = v_1 - v_2$$

$$v_c = \frac{1}{2}(v_1 + v_2)$$

$$V_o(t) = A_d v_d(t)$$

$$V_o(t) = A_d v_d(t) + A_c v_c(t)$$

$$v_1(t) = v_c(t) + \frac{1}{2} v_d(t)$$

$$v_2(t) = v_c(t) - \frac{1}{2} v_d(t)$$

$$CMRR = \left|\frac{A_d}{A_c}\right|$$

$$CMRR = 20\log_{10}\left|\frac{A_d}{A_c}\right| \text{ dB}$$

$$BW = f_H - f_L$$

$$Q = \frac{f_o}{BW}$$

$$f_o = \sqrt{f_H f_L}$$

$$\omega_o = \frac{1}{RC}$$

$$f_o = \frac{1}{2\pi RC}$$

$$K = 1 + \frac{R_f}{R_i}$$

$$(BW_{cl})(A_{cl}) = \text{unity gain BW}$$

$H(s) = \frac{K}{(s/\omega_O + 1)}$; low pass filter general form

$H(s) = \frac{K}{(\omega_o/s + 1)}$; high pass filter general form

End of paper.